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The implications of computer technology and architecture are discussed with reference to school building design. A brief introduction is given of computer applications in other fields leading to the conclusions that computers alone cannot design school buildings but may serve as a useful tool in the overall design process. Specific examples are given in--(1) production scheduling, (2) detail drawing, (3) CPM and PERT programming, (4) simulation of college space utilization, (5) hospital layout, and (6) site selection. The computer is also described as a design aid, solving structural problems, making sketchpad drawings, graphic stress analysis. Future uses for computers are mentioned based on an expanding and devised technology, and the capability of architects and designers to adapt to new methods. (MM)

CAN THE COMPUTER DESIGN A SCHOOL BUILDING?

CHARLES ROBERTS

The computer can guide rockets, missiles and planes, and land planes successfully. It can print a daily paper; match male and female personalities for compatibility; predict presidential elections; control the airways of the world; read books; review literature; write letters; keep track of astronauts heart beat, blood pressure, blood count, temperature, respiratory rate, and general health conditions as they orbit the earth; and operate other complicated machines. At the Sloan-Kettering Institute for Cancer Research a computer is being set up to analyze the records produced by continuous monitoring of the heart. It may ultimately be able to read the incoming electrocardiogram more accurately than human eyes, compare this with its memory patterns, and instantly warn doctors of sudden or dangerous changes. With the computer's ability to analyze quantities of data, and monitoring's capacity to provide dynamic measurements of the body's functions, great progress in diagnostic accuracy may be expected. A "unified field theory" of medicine, tying together all physiological phenomena, may be just over the horizon.

The machine is taking over, but don't get too worried about these mechanical brains making man obsolete. Like all other great inventions—from the cigaret machine to TV—they still need someone standing by to kick them when they refuse to work. Someone has composed a little jingle:

Within the automatic home
The housewife lolls and lingers;
No longer plagued by dishpan hands;
Instead push button fingers.

Yes, automation is here. New factories are replacing old with fewer men and more machines. Companies which use large numbers of clerks are using machines to relieve them for other jobs. You recall how a computer is used to review your income tax return for discrepancies, omissions, and accuracy.

Now to the question for consideration today: Can computers design school building? No. The computer can do only those things which it is told to do. It cannot create. It is a logical machine, which understands only a few complicated languages. It will calculate, solve mathematical equations, read, write, store, and pull out of storage. But it cannot make choices. At the fork in the road, both roads will be traveled if they are open.

The computer operates and is controlled by an electrical current. When the switch is open the current stops; when it is closed the current

passes through. It reads a binary language: open—shut; on—off; yes—no; or 1-0. If numbers are stored in the machine in positions 0040 to 0044 and other numbers are stored in positions 6238 to 6242 and it is given simple instructions—add what is in positions 0040-0044 to what is in positions 6238-6242—it will do that and nothing more; and it will perform this task in microseconds. It is understandable then that the computer will perform tasks more quickly and more reliable than the human machine, and by standardizing a set of instructions—programming—procedures may be speeded up tremendously.

How has the computer been used by planners and designers? Designers and planners for the automobile industry, boating industry, computer industry, aircraft manufacturers, road building industry, bridge construction industry, the building industry, and perhaps others have used the computer in various ways to their advantage.

Chrysler Corporation uses electronic computers to do a better and much faster job of preparing parts lists and making production releases for a new model year. The techniques not only save time and eliminate mounds of paper work; they also serve to spread the work load more uniformly so as to reduce the burden of paper work at the time the manufacturing organization is making ready for a changeover. The computer is used to produce parts lists complete with all data, including interchangeability among product groups. The computer also updates existing parts lists and revises the memory system in accordance with the flow of engineering changes. With this new system the time required to produce a complete set of parts lists, or to update existing material has been reduced from weeks to only 48 hours.

Fabricators are using the computer to produce detailed drawings of structural-steel framing members. The manner in which the final design is achieved is an important and interesting feature. The engineer prepares structural characteristics of the individual components—length, cuts, rivet holes, and connections—on a layout of floor framing system. On the layout, he locates columns, specifies nature of equipment to be supported and the loads to which the floor is subjected. From this input forms are prepared which are subsequently keypunched and fed into the machine. When instructed to calculate and draw according to some already prepared formulae, the computer and the attached plotter will determine the size of the members and will draw them in place.

Two programs, Critical Path Method (CPM) and Performance Evaluation Recording Technique (PERT), have been used by school boards in constructing school buildings. CPM is a device to break down all the steps in the design and construction of a school building and arranges them into a specific, logical order. It takes into consideration the interrelationships and coordination of all contractors and their subcontractors listing all the activities on a periodic progress report. The method highlights critical

activities and detects trouble spots early, giving the school administrator the ability to react rapidly to changing conditions.

At the time CPM was being developed, PERT was being put together for the Navy by Booz, Allen, and Hamilton. It was developed to keep track of research and development work on the Polaris missile.

The difference between CPM and PERT are: the former is accurate in its cost-time function predictions while the latter (PERT) tries to predict probabilities for the estimates of job duration. There is no magic about these applications. All details and conditions about possibilities must be recorded and stored in the machine which calculates the results when certain other probabilities (programs) are fed in to interrelate with the former. In substance the machine predicts events under simulated circumstances.

The computer was employed to pare an estimated $3 million from the construction cost of a junior college in St. Louis County recently. In obtaining this economy, the same techniques employed by aerospace engineers in simulating the performance of aircraft and space vehicles were applied to the planning of the new, 4,500-student college. The computers at McDonnell Automation Center, which have been used to simulate earth orbit and rendezvous of space vehicles, were employed to simulate the operation of the new college. The expected programs of each of the 4,500 students, the number and size of planned instructional spaces, available faculty, and various time patterns for class scheduling were fed into the computer. In less than 30 minutes the computer produced a complete college schedule that indicated what percentage of a 45-hour college week (8 a.m. - 5 p.m.; Monday - Friday) the college's instructional spaces—iecture halls, classrooms, shops, and laboratories—would be in use.

Twenty-seven different runs were made with different ratios of classroom sizes, the number of lecture halls, the number of faculty, etc. After 27 runs, they selected the best room and seat utilization and provided the architects with educational specifications for 85 spaces—several rooms and 100,000 square feet fewer than they thought possible. With building costs mounting to some $20 per square foot a savings of $2 million was realized on instructional space alone and by about $3 million when corridor and other auxiliary space was taken into account.

Stanford University has developed a scheduling manual, which outlines computer procedures for scheduling school facilities. The concept here is that the school day and year can be lengthened which better utilizes the facilities.

James A. Soule[illegible]r, of the Los Angeles firm of *Bolt Beranek and Newman, Inc.* showed architects how he used a computer to design a hospital. He stored some 40,000 data items consisting of nurses, patients, and doctors' travel time to and from operating rooms, coffee, supply room, and equipment room on a computer, which printed out an origin-destination Matrix.

Armed with this detailed information, he tested three schemes: a nursing unit tower with 100 beds per floor rising from a large low base containing diagnostic treatment and supply spaces; an intermediate scheme with a lower tower containing 200 beds per floor; and a third scheme with 250 beds per floor.

From all the bits and pieces of information the computer print-outs showed that Scheme II cut the total Scheme I man-hours spent in travel by one-third. Scheme III reduced the man-hours spent traveling in Scheme II by nearly 60% and thus clearly provided the most efficient travel design of the three.

The computer analyses the problem components quantitatively and qualitatively and what is normally conceived somewhat fuzzily as a problem of "intuition" is brought into sharper focus. The scope of the architect's art is expanded in the process.

The Air Products and Chemicals, Inc. selected a 500 ton/day air separation plant site near Wilmington, Delaware with the assistance of a computer. Thousands of data items, consisting of supply, demand, flow, cost of fuel, access to supply and demand, location of supply and clients, a pattern of distribution, time to construct plant, proximity to transportation facilities, and off season productions, which could be formed into linear equation were fed into the computer. It not only pinpointed the location but indicated when the growing market would support such a plant.

In Boston last December, 500 architects assembled, listened, and discussed the computer as an aid to the architect. After allaying the fears of some that the machine was going to take over, speakers illustrated some ways the computer could relieve the architect of some time consuming tasks and even projected ways it could be used in the future.

Boston structural engineer William LeMessurier explained how the Structural Engineering Systems Solver (STRESS) has been used in his office. It is a standardized computer program that solves structural problems. It is designed to accept simple language instructions which most anyone could use. Other uses described were calculations for duct sizes for air conditioning and lighting fixtures for light requirements.

Professor Steven Coons of MIT showed a sketchpad process which draws a picture. In Sketchpad, the operator uses a light-sensitive pencil containing a photo-diode to draw on the surface of a tube similar in appearance to a TV screen. The light pencil reacts to minute glowing dots on the surface of the screen sending an electrical impulse back to a computer that registers the position of the dots with which the pencil made contact.

The machine is programmed so that the patterns roughly traced by the light pencil can be formalized into exact images: straight lines, equilateral polygons, perfect circles. The size of the image can be increased, decreased,

or duplicated and the orientation rotated. An image can also be erased and brought back. An operator can draw a plan in one quadrant of the screen and simultaneously produce two elevations and a perspective in the two other quadrants. One can readily visualize the prospects this has for form design.

These light pencil techniques can be used in several ways. The operator takes the light pencil and draws a cantilevered truss on the screen. He then feeds in the loads on the truss and instructs the machine according to the STRESS programs to give him the stresses in the individual members. If he does not like the results, he can modify the truss and go through the whole procedure again, evenutally coming up with an optimum.

Professor Serge Chermazeff of Yale implored the architects to come out of their "shells" and accept the challenge of solving problems of environmental design at a generalized level, the architect being an agent who adapts an established building type and form to a particular set of circumstances. "We can now say good-by to the slow laborious process that makes a guinea pig of every client."

From the Boston conference it was possible to envisage, according to the reporter, in the not too distant future architects and planners being able to receive engineering data and evaluation of functional characteristics almost instantly, at any stage in the design process; and specifications and working drawings of the finished product could be produced with great rapidity using computerized techniques.

Can the computer design school buildings? No. But, you see, it has been used effectively to assist in the design procedures and will be used in the future even more effectively. The use of the computer has been here only a short time and if improvements continue in the future at the same rate as they have in the last ten years, we will have a more sophisticated computer which will perform more complicated tasks at an even greater speed.

The first computer was a huge box of vacuum tubes. The present day computer is built with transistors and is about the size of an ordinary refrigerator, but the computer of tomorrow will have film with magnetized dots as conductors and will be the size of an attache case. Instead of a speed of microseconds (1000th of a second) it will produce in nanoseconds (1,000,000th second). Instead of reading simple instructions in numerical terms, it will read any form of printed material and will accept instructions and produce output in audio form.

In this space age when new knowledge is exploding constantly—so fast it is almost impossible to record all of it—it is of the utmost importance for architects and planners to keep abreast of new techniques. In a recent conference in Detroit some experts warned that architects and planners must ride the computer wave of the future or be left behind. School buildings

cannot be designed by computers but computers can be used advantageously by architects and planners. Let's take advantage of the new tool!

In the question and answer period which followed, a number of points were made:

It was learned that a school district with limited funds would be able to use computer services in designing a school building by various management techniques. A Central Computing Agency is being considered for states and larger school districts under Title V. Funds are also available for local district computer services through various offices of H.E.W.